

teeth. The number of rotor teeth exceeds the number of stator teeth so the rotor teeth overlap the stator teeth. This improves starting torque in a desired direction of motor rotation.

#### DEPR:

The rotor teeth of motor 50 are spaced so that they overlap a stator pole. This is done to increase the amount of starting torque in the direction of desired motor rotation. For motor 50, the spacing between rotor teeth is given by the formula:  $\frac{360}{N} \times \frac{R}{S}$  where: 360 is the number of degrees in a circle,

#### DEPR:

While respect to rotor assembly construction, if the stator assembly has only one tooth per pole, then the rotor teeth have a step gap construction to improve starting torque in the desired direction of rotation. If the stator poles have two teeth per pole, then it is important that the rotor have a prescribed number of required teeth based upon the above formula. In order to improve starting torque in a desired direction of motor rotation, the rotor teeth should overlap the stator teeth of other phase poles when one phase is at maximum inductance. The number of rotor teeth is limited by the ability to construct a stator having the appropriate calculated spacing between stator teeth. Thus, as indicated the spacing formula, so long as the result of the spacing calculation exceeds approximates and is

## United States Patent (19)

Horn

(11) Patent Number: 5,239,217  
(45) Date of Patent: Aug. 24, 1993

### REDUNDANT SWITCHED RELUCTANCE MOTOR

Inventor: Guy E. Horn, County of St. Louis, Mo.

Assignee: Emerson Electric Co., St. Louis, Mo.

Appl. No.: 084,149

Filed: May 18, 1992

Int. Cl. H02K 5/24; H02K 1/24

U.S. Cl. 310/81; 310/289; 310/158

Field of Search 310/31, 161, 234, 261, 310/259

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Primary Examiner—Emanuel T. Voelke

Assistant Examiner—Judson H. Jones

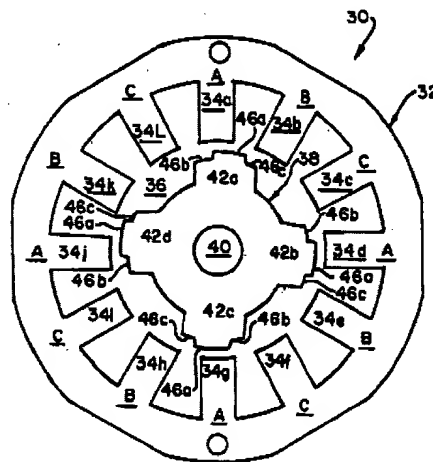


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#### ABSTRACT

A multiple phase switched reluctance motor (50). A stator assembly (32) has a plurality of inwardly salient teeth (34a-34j) terminating at a central bore (36). A rotor assembly (38) is disposed for rotation in the bore and has a plurality of rotor teeth (42a-42j). The stator assembly has at least one redundant pole set for each motor phase. The rotor assembly has a corresponding proportional number of rotor teeth. The redundancy of the poles helps distribute overlapping forces on the motor assembly. This lessens the effect of these forces and reduces motor noise produced by the assembly in response to the forces. In addition, the stator can have multiple teeth per pole and the rotor a multiple of the determined rotor teeth. The number of rotor teeth exceeds the number of stator teeth so the rotor teeth overlap the stator teeth. This improves starting torque in a desired direction of motor rotation.

14 Claims, 8 Drawing Sheets



DOCUMENT-IDENTIFIER: US 4348605 A  
TITLE: Electrical reluctance machine

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#### DEPR:

During clockwise rotation (as viewed in FIG. 4) and with the rotor position shown in FIG. 4, two of the rotor poles, namely those which are nearest the stator poles B4 and B7, are in a drawing-in position, whereas the two rotor poles which overlap the stator poles B5 and B2 are in the process of moving away from these stator poles. Since the magnetic flux is approximately equally great at all four overlapping points, it is easy to believe that the resultant torque would be almost equal to zero. This, however, is not the case, since the m.m.f. in the overlapping zones between a stator pole and a rotor pole to a great extent determines the torque that the stator pole exerts on the rotor pole.

#### CCOR:

310/168

#### United States Patent (19)

[11] 4,348,605

Török

[45] Sep. 7, 1982

#### [54] ELECTRICAL RELUCTANCE MACHINE

4,348,605 4/1981 Jarret et al. 310/163 X

[73] Inventor: Vilmos Török, Lidingö, Sweden

Primary Examiner—Donovan F. Duggan  
Attorney, Agent, or Firm—Pollock, Vancil Sands & Pridley

[75] Assignee: ASEA Aktiebolag, Vasterås, Sweden

[21] Appl. No.: 181,890

[22] Filed: Mar. 19, 1980

[30] Foreign Application Priority Data

Mar. 30, 1979 [52] Sweden 7902843

[31] Int. Cl. 2 H02K 29/06

[32] U.S. Cl. 310/161; 310/153

[33] Field of Search 310/161, 162, 163, 168, 310/154, 155; 310/170

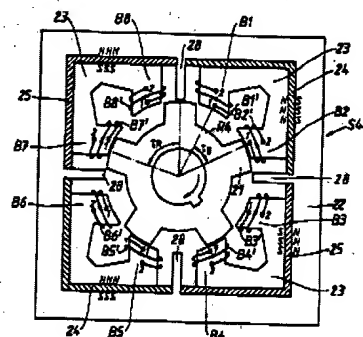
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**ABSTRACT**  
A reluctance machine comprises a rotor having a plurality of unwound salient rotor poles, and a stator with an even number of mutually equal groups of salient stator poles evenly distributed around the inner circumference of the stator unit, each stator pole being surrounded by a respective working coil. The stator poles belonging to the same group have the same polarity and also the same premagnetization. The polarity is determined by the working coils being distributed between at least two working windings which are each provided with a rectifying diode. However, two stator poles, whose working coils belong to one and the same working winding, there is at least one stator pole which supports a working coil belonging to some other working winding.

14 Claims, 23 Drawing Figures



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Full

DOCUMENT-IDENTIFIER: US 6359360 B1  
 TITLE: Electronically switched two phases reluctance machine

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DEPR:

There is a correct function of the machine when the overlapping of the rotor (121) or stator poles 111 is selected such that, when the stator-rotor poles of the phase X correspond to each other (position tooth-tooth), the stator-rotor poles of the second phase are displaced around the angle  $w$  (position tooth-gap). The position of the phase magnets with respect to the angle  $w$  (=pole width, =gap width) is the following:

DEPR:

The poles 111X (the yokes 11X) are fixed in such a way, so that this happens, that they begin to attract straight rotor teeth 121, when these teeth (121) have passed over the maximal overlapping with the poles 111Y.

CCOR:

310/168



US006359360B1

(12) United States Patent  
 Lungu

(10) Patent No.: US 6,359,360 B1  
 (45) Date of Patent: Mar. 19, 2002

(54) ELECTRONICALLY SWITCHED TWO PHASES RELUCTANCE MACHINE

4,504,513 A 4/1986 Finken et al. 318,701  
 5,015,923 A 5/1991 Hancock et al. 3102,68

(70) Inventor: Ioana Lungu, Str. Trandafir nr. 5 GLA ap-40, sector 3, RO-74381 Bukarest (RO)

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(\*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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 One page description entitled Retarder; dated Feb. 15, 1969; inventor: Takayuki Suzuki; application No. 64-35900.

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 Assistant Examiner—Dang Dinh Le  
 (74) Attorney, Agent, or Firm—Kelly Bousfield Lowry & Kelley, LLP

(21) Appl. No.: 09/308,538

(22) PCT Filed: Nov. 19, 1997

(86) PCT No.: PCT/RO97/00007

§ 371 Date: Dec. 24, 1999

§ 102(a) Date: Dec. 24, 1999

(87) PCT Pub. No.: WO98/23024

PCT Pub. Date: May 28, 1998

(30) Foreign Application Priority Data

Nov. 20, 1996 (RO) ..... 94-02186

(51) Int. Cl.<sup>7</sup> ..... H02K 17/00; H02K 17/42

(52) U.S. Cl. .... 310/168; 310/171

(58) Field of Search ..... 310/166, 168, 310/449 R, 254, 171, 112

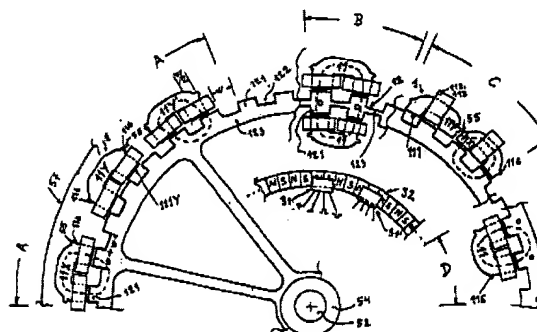
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12 Claims, 2 Drawing Sheets



has at least one redundant pole set for each motor phase. The rotor assembly has a corresponding proportional number of rotor teeth. The redundancy of the poles helps distribute ovalizing forces on the motor assembly. This lessens the effect of these forces and reduces motor noise produced by the assembly in response to the forces. In addition, the stator can have multiple teeth per pole and the rotor a multiple of the determined rotor teeth. The number of rotor teeth exceeds the number of stator teeth so the rotor teeth overlap the stator teeth. This improves starting torque in a desired direction of motor rotation.

**DEPR:**

The rotor teeth of motor 50 are spaced so that they overlap a stator pole. This is done to increase the amount of starting torque in the direction of desired motor rotation. For motor 50, the spacing between rotor teeth is given by the formula:  $\frac{360}{\text{number of rotor teeth}}$  where: 360 is the number of degrees in a circle,

**DEPR:**

While respect to rotor assembly construction, if the stator assembly has only one tooth per pole, then the rotor teeth have a step gap construction to improve starting torque in the desired direction of rotation. If the stator poles have two teeth per pole, then it is important that the rotor have a

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5,239,217

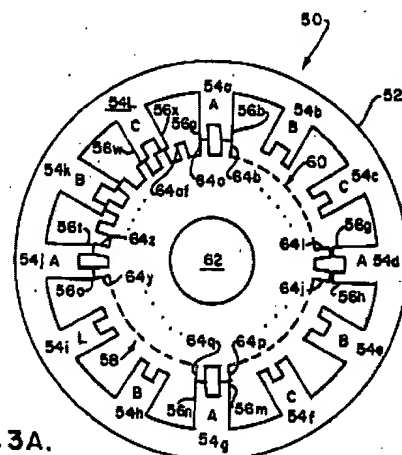


FIG. 3A.

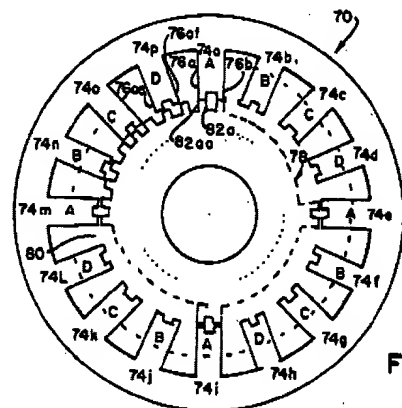


FIG. 4.

prescribed number of required teeth based upon the

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schemes utilizing  
overlapping bi-polar excitation currents are envisioned.  
One such bi-polar  
excitation scheme is illustrated in FIGS. 13A-13C.

#### DEPR:

Because overlapping currents are utilized in the energization scheme of FIGS.

13A-13C it is possible to produce more torque as a function of the changes in the mutual-inductances between the various phase windings. Thus, the total torque output for the machine 90 of FIG. 9, T, when energized with overlapping currents, may be generally expressed as: ##EQU31##

#### DEPR:

FIG. 13B illustrates an exemplary energization scheme utilizing overlapping bi-polar currents to produce positive output torque in a desired direction.

According to the illustrated energization scheme: (i) the phase A winding is energized with positive current during the intervals of rotor rotation over which the self-inductance of the phase A winding is increasing (e.g., the 0.degree.-30.degree., 90.degree.-120.degree. and 180.degree.-210.degree. intervals); (ii) the phase B winding is energized with negative current during the intervals of rotor rotation over which the self-inductance of the phase B winding is increasing (e.g., the 0.degree.-30.degree., 90.degree.-120.degree. and 180.degree.-210.degree. intervals); (iii) the phase C winding is energized with positive current during the intervals of rotor rotation over which the

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Feb. 2, 1999

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5,866,964

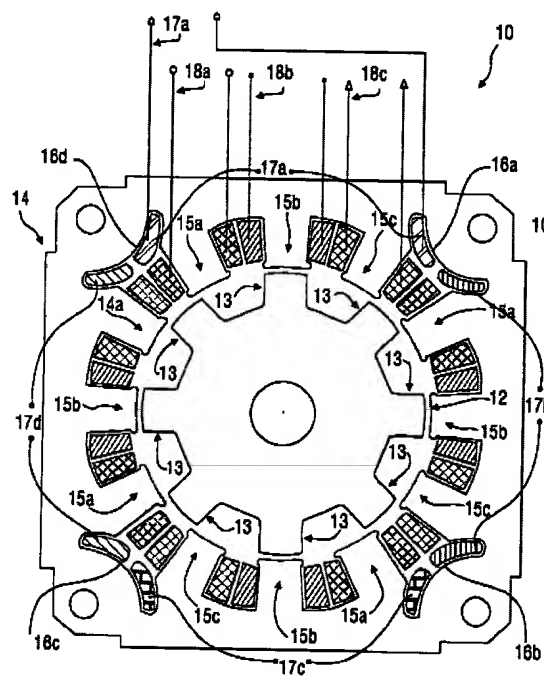


FIG. 1

overlap with the energized stator poles associated with the phase A winding (e.g., a 9 degree overlap). As illustrated in the figure, the flux flow through the energized phase windings is extensive and, depending on the magnitude of the current flowing in the phase A winding, will often be limited by the saturation characteristics of the material used to construct the stator. Further, as reflected in FIG. 20A, all of the flux flow in the traditional machine is directed through the energized stator poles, thus contributing to localized saturation of the stator.

## CLPR:

16. The doubly-fed reluctance machine system of claim 15 wherein the single excitation converter provides non-overlapping, uni-polar currents to the electrical connections between the phase windings from the first and second sets.

## CLPR:

17. The doubly-fed reluctance machine system of claim 15 wherein the single excitation converter provides overlapping bi-polar currents to the electrical connections between the phase windings from the first and second sets.

## CCXR:

310/166

## United States Patent [19]

Tung

 US005811905A  
 Patent Number: 5,811,905  
 Date of Patent: Sep. 22, 1998

## [54] DOUBLY-FED SWITCHED RELUCTANCE MACHINE

[75] Inventor: Yihua Tung, St. Louis, Mo.

[73] Assignee: Emerson Electric Co., St. Louis, Mo.

[71] Appl. No.: 779,570

[22] Filed: Jan. 7, 1997

[51] Int. Cl.<sup>7</sup> H02K 19/00; H02K 19/10; H02K 19/12

[52] U.S. Cl. 310/179; 310/185; 318/254; 318/701

[58] Field of Search 310/179, 185, 310/185, 197, 184, 162, 165, 168; 318/254, 701

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 Primary Examiner—Steven L. Stephens  
 Assistant Examiner—B. Mullin  
 Attorney, Agent, or Firm—Armaki, White & Durkin

## [57] ABSTRACT

A doubly-fed switched reluctance machine in which at least two sets of phase windings are energized to produce desired output torque is disclosed. Also disclosed are dual and single power converters for energizing the doubly-fed machine as well as exemplary excitation schemes position. Sensorless techniques and systems for controlling the doubly-fed machine, and other machines having fully-phased or fractional-phased windings, are also disclosed.

22 Claims, 35 Drawing Sheets

